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KME is one of the world’s largest manufacturer of copper and copper alloy products. KME manufactures a wide range of semi-finished, finished and special products at locations across Europe, North America and Asia.

The Company

KME’s corporate goal is to develop and manufacture products that meet customer demands, finding solutions for their specific applications, and providing services as a long-term partner. KME’s strategy for accomplishing this goal is based on a highly skilled and experienced workforce. KME has the ability to invent and develop new materials and innovative production processes via ongoing advancement and training of our employees and the continual improvement of its engineering capabilities.
The continuous casting of steel has seen major technological improvements over the past decades. This has led to considerable increase in productivity and product quality necessary to ensure survival in today’s highly competitive environment. The Engineered Products Division of KME has been instrumental in achieving many of these process improvements.

The advances in casting technology were made possible by the development of high-performance moulds made of copper alloys. KME was involved in these activities right from the very beginning and has continued to set milestones in the development and production of copper moulds for the continuous casting and re-melting of steel and non-ferrous alloys.

The Engineered Products Division was formed as part of a strategic reorganisation, with the aim of providing a flexible solution to market demands and improving the customer orientation of our business. Our customers are manufacturers of steel and non-ferrous metals, casting machine builders and maintenance companies throughout the world.

The division not only serves our customers as a general contractor for the production of mould assemblies, but also as a partner in solving the many technological challenges in the field of continuous casting.
The performance requirements that have to be met by moulds and mould materials depend on the specific application and the levels of stress involved. These stress levels are mainly predetermined by the machine and casting parameters, which means that many different cast shapes are needed, depending on the type and construction of the mould. When designing a new mould, the correct profile must be chosen in order to achieve high product quality, optimal casting speeds, smooth casting operations and long service life of the moulds.

A good example of this are the requirements placed on modern mould materials for near-net-shape-casting processes which have been developed in recent years. Here, very high casting speeds are achieved and a much higher proportion of the liquid metal must solidify in order to form a sufficiently stable strand shell. The resulting extreme temperatures demand moulds with higher strength levels. At the same time, a high alternating thermal stress can occur, for example on casting rolls. This wide variety of requirements placed on moulds has to be met by highly developed materials and system expertise.

In order to be able to offer our customers future-oriented solutions for the wide variety of different casting technologies and taking into account the constantly changing requirements on moulds and mould materials, KME is conducting research in the following fields of mould technology:

- Mould engineering
- Mould materials
- Mould manufacturing
- Mould coatings

Unlike all other manufacturers, KME has all the key technologies for the production of high-performance continuous casting moulds under one roof. This unique combination of expertise, numerical simulation, calculation methods and long-standing experience in the field makes us a highly qualified partner in all mould related questions that arise.
The range of mould materials developed and produced by KME allows appropriate selection of the optimum copper alloy for individual applications. However, in order to achieve high performance, optimum steel quality and a long service life of the moulds, further engineering work is generally necessary – particularly when casting parameters have been changed from the original concept in order to achieve higher casting outputs or produce special types of steel. This is where KME’s mould engineering service comes into play, supporting its customers in upgrading continuous casting moulds and optimising system parameters and mould constructions.

Using FEA and CFD to calculate the mould stresses based on 3D CAD modelling allows accurate simulation of the mechanical and thermal stress factors involved in each case. Mould dimensioning, tapering and the specification of cooling conditions are based on the results of these calculations. KME can provide detailed support on the design of new moulds. On request, KME will also do the entire detailed engineering based on the machine builders’ design drawings.

**Dimensioning**
When designing a mould for slab, bloom or billet, each case must be considered individually. The main variables that play a role are the construction of the casting machine, the steel grades to be cast, the desired casting speed and the cooling conditions.

**Mould taper**
The taper is one of the most important parts of the mould design, especially in case of non-adjustable moulds. When specifying the mould taper the steel grade and the casting parameters are the main factors that must be taken into account.

From a theoretical approach, the optimal taper of a mould can only be defined for one steel grade (due to its specific shrinkage behavior) and for one specifically defined casting condition, i.e. superheat of the liquid steel, casting speed, etc.

This means, a taper can always only be a compromise that has to fit for a wider range of casting conditions. Because tailor-made parabolic tapers fulfill this task better, they are nowadays the dominating design, while tubes with linear, double or quadruple tapers are getting less in usage.

**Cooling conditions**
Another important factor for designing a mould is the adjustment of cooling conditions and casting parameters in order to ensure good system productivity and product quality.

For this purpose, KME performs CFD (Computational Fluid Dynamics) calculations of the water flow between cold face of the mould and the water box. In combination with the thermal load calculation of the hot-face, this will give a detailed analysis of the thermal and mechanical stresses on the mould during the casting process and will support the optimisation of the design.
Advanced Smart Mould Technology for Improved Performance

In recent years, significant progress has been made in the development of high tech and automated steel production processes. KME is supporting this effort with the development of our ‘Advanced Smart Mould Technology’. This new technology allows for the digitalisation of key mould operating parameters that can then be optimised for improved continuous casting results.

Mould Temperature Monitoring
Monitoring the temperatures seen by the copper mould during casting is critical for process control and to understand the dynamic solidification processes during casting. Therefore, robust temperature measurement techniques are a basic requirement for the digitalisation process. KME offers two technologies for temperature measurement and thermal monitoring:

- The application of thermocouples in different designs and arrangements, depending on the type of casting mould.
- The application of fibre optic measuring systems with Bragg elements that offer a substantial improvement in resolution and quality of the temperature information.

KME has the technical know-how as well as experience to select and design these systems. Furthermore, we also have the capability to handle the installation including the very difficult deep-hole drilling (up to 2500 mm depth and 1.2 mm diameter) in both mould plates and mould tubes. Thus, we can offer a complete packaged solution for either of these systems.

Advanced Mould Organizer

QR Mould Identification
KME has developed a new QR-code based system that provides mould identification and tracking. This technology is able to simplify the often-difficult task of determining the specific mould being used in the casting operation and/or maintenance shop. In the future, the QR-code will be linked to various other informations, such as mould geometry, and other product data.

Mould Sensor
A further development to broaden the KME Advanced Smart Mould Technology is the integration of a special mould sensor that has the ability to communicate data via a ‘Bluetooth’ interface. This will enable easy access to key operating data such as the mould’s time in service, the remaining rework potential, and other information. By using a companion software tool, data from the chip can be evaluated and archived for later analysis.
MOULD TUBES FOR
BILLETs ANd BLOOMS

KME develops and supplies the whole range of mould tube geometries and dimensions in use today, from small rectangular tubes right through to large-format round mould tubes. Our customers can select from various tapers and special internal geometries, such as AMT®, textured or WAVE® solutions.
KME manufacturing range for mould tubes

<table>
<thead>
<tr>
<th>Materials</th>
<th>Cu-GS, CuAg-GS, ELBRODUR® G, ELBRODUR® GR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>- Square, rectangular, polygonal, round, beam-blank</td>
</tr>
<tr>
<td></td>
<td>- Straight or curved</td>
</tr>
<tr>
<td></td>
<td>- Outer contour parallel</td>
</tr>
<tr>
<td></td>
<td>- Internal geometries: parallel, tapered, part-tapered, multi-tapered or parabolic</td>
</tr>
<tr>
<td></td>
<td>- CONVEX, DIAMOLD®</td>
</tr>
<tr>
<td></td>
<td>- AMT®</td>
</tr>
<tr>
<td></td>
<td>- ATM (KME patent)</td>
</tr>
<tr>
<td></td>
<td>- WAVE® mould tubes (KME patent)</td>
</tr>
<tr>
<td></td>
<td>- Textured mould tubes</td>
</tr>
<tr>
<td>Coatings</td>
<td>- Chrome</td>
</tr>
<tr>
<td></td>
<td>- Advanced chrome, TOPOCROM®</td>
</tr>
<tr>
<td></td>
<td>- Multi-Layer-Coating</td>
</tr>
<tr>
<td>Sizes</td>
<td>- no limits</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>- no limits</td>
</tr>
<tr>
<td></td>
<td>- recommended for large sizes max. 30 mm</td>
</tr>
</tbody>
</table>
To optimise the casting process and product quality even more, KME offers innovative solutions that can be combined to suit the customer’s specific needs for solving metallurgical or process-related technical problems.

**WAVE® tubes**
The WAVE® mould has a patented design that superimposes a series of undulations onto the hot-face side of the mould, causing a mirror image to be formed on the billet surface as it begins to solidify. These two surfaces will interlock and the shell will be guided through the length of the mould while restraining any movement from side-to-side.

The mould and shell are thus “coupled” together to such a degree that a more equal heat extraction, and hence uniform shell growth, occurs during this critical time. The result is improved billet shape and internal quality, as well as increased mould life.

This special design is also applicable for round sizes: Round WAVE® tubes.
**Textured tubes**

KME has developed a new method for controlling the heat removal in a mould tube. Using a specially developed manufacturing process, a texture can be applied to the casting surface of the mould tubes. This allows the heat transfer to be moderated in specific areas of the mould.

**ATM tubes**

The ATM design is an economical way to replace bloom mould plates by a repairable mould tube design while keeping the existing waterboxes. Corner gap problems are eliminated.

The ATM design optimises the mould cooling over the entire surface area of the mould by using a uniform water gap cooling type, while reducing the internal stress in the copper due to the special low-stress bolting technology.

Furthermore, the design offers more stability to the mould wall compared to conventional tube designs and is therefore favourable for large sections.
KME has developed various technology packages for the continued development of the moulds used in the casting of bloom and slab shapes. Based on a precise analysis of the cooling water flow and the load on the moulds arising from the process, an improvement in the service life can often be achieved through local optimisation of the cooling geometry.

Also completely new designs for cooling improvements were established in recent years, such as optimised-deep-drilled plates, chamfered narrow-faces with special edge cooling and ASM® mould plates.

**ASM® mould plates**

KME engineers have developed ASM® (Advanced Slab Mould) technology to optimise the cooling of standard mould plates by converting the slot cooling design into a uniform water gap cooling type.

By using filler- or adapter plates in conjunction with the patented AFM® mounting, it is possible to reduce the working load on the moulds and to improve casting efficiency and strand quality with adjusted cooling water flow especially for curved mould plates. A significant advantage of the ASM® technology is that existing moulds can be converted without requiring high investment.

**Reduced heat dissipation**

For the casting of steel grades that are prone to cracking, KME offers materials with reduced thermal conductivity as well as solutions with textured hot-faces for mould plates to achieve a reduced heat transfer in the mould.

KME’s strength in technical design together with our available materials and coatings, enables us to develop tailor-made solutions for each customer as required.
## Manufacturing range for mould plates

<table>
<thead>
<tr>
<th>Materials</th>
<th>CuAg-GS/NS, ELBRODUR® H, ELBRODUR® G/GP/NS/GP, ELBRODUR® NIB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate design</td>
<td>- Cooling slots or cooling drills or water gap cooling type</td>
</tr>
<tr>
<td></td>
<td>- Casting surfaces straight or machined to casting radius</td>
</tr>
<tr>
<td>Coatings</td>
<td>- Nickel</td>
</tr>
<tr>
<td></td>
<td>- Nickel + chrome</td>
</tr>
<tr>
<td></td>
<td>- Nickel alloy</td>
</tr>
<tr>
<td></td>
<td>- Nickel alloy + chrome</td>
</tr>
<tr>
<td></td>
<td>- Metal-Ceramic</td>
</tr>
<tr>
<td>Sizes</td>
<td>- Practically no limits</td>
</tr>
</tbody>
</table>
Tubes, plates and rolls
New continuous casting systems must guarantee high productivity, ensure good product quality and drastically reduces the specific energy consumption from raw material to finished product. These goals are being pursued with the development and introduction of near-net-shape-casting processes. KME played a decisive role in the development of these technologies by developing materials, optimising geometry and cooling and adapting the coating for the moulds. By engineering new mould concepts such as the Advanced Funnel Mould (AFM®) and the Advanced Beam blank Mould (ABBM), KME continues to set milestones in the development of moulds for near-net-shape-casting technology.

Moulds for beam-blank casting
A multi-part plate mould or a mould tube can be chosen for beam-blank casting. Plate constructions give a greater degree of freedom when specifying the mould taper and coating, whereas tubes make it possible to use casting oils. Repair techniques for both types of moulds are available at KME.

ABBM – Advanced Beam Blank Mould
The KME Advanced Beam Blank Mould is an innovative development in mould technology for beam-blanks. The combination of a thin-walled copper plate with a water gap cooling type and a support plate permits the separation of functions in this mould type. For the first time, it is now possible to use thin-walled copper plates for optimised heat dissipation without losing any of the maintenance-friendly qualities of plate construction.

Mould plates for thin slab casting
The casting of thin slabs is the most common method of near-net-shape technology used today. The mould takes on particular importance for the performance of the system. Due to the changed surface/volume ratio in this method, about 50 % of the slab thickness solidifies in the mould, compared with 10 % in conventional slabs. This means that large amounts of heat have to be removed by the mould and the copper is subject to extreme thermal stresses. KME’s development of new materials and the in-house production are decisive advantages that can be utilised here. Today, KME manufactures CSP®, ISP®, ESP®, FTSC® and DUE® mould plates for thin slab casting.

AFM® – Advanced Funnel Mould
KME has engineered the innovative Advanced Funnel Mould (AFM®), which consists of a thin-walled copper plate and an adapter plate. The thin copper plate allows high heat transfer rates, which is a basic requirement for improved casting efficiency. In addition, the thickness of the mould plate is adapted to the specific heat load in different areas of the mould. Combined with the water gap cooling design this results in homogeneous surface temperatures for uniform melting of the casting flux, and thus improved slab surface quality.

A patented connection to the adapter plate allows a controlled heat expansion of the copper plate during casting, in order to reduce the operating stresses in the copper plates.

ATSM – Advanced Thin Slab Mould
The ATSM Mould is KME’s newest design upgrade for thin slab caster. Like the AFM®- and ABBM-mould the ATSM-mould is compatible with existing water boxes. It consists of an improved copper plate design (Patent Applied) with broad cooling fields for a homogenous cooling and an innovative anti-bulging system (Patent Applied) to counteract meniscus bulging.

As additional feature for easy maintenance the ATSM design uses a few swivelling filler plates instead of numerous filler bars as used at the standard designs.

With this feature the ATSM offers maintenance-friendly access to the water-cooled copper surfaces for easy inspection and cleaning.
### Manufacturing range for near-net-shape moulds

<table>
<thead>
<tr>
<th>Type of mould</th>
<th>Form</th>
<th>Materials</th>
<th>Design</th>
<th>Sizes</th>
<th>Coatings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin slab</td>
<td>Plates</td>
<td>CuAg-NS</td>
<td>- With cooling slots or drilled cooling channels</td>
<td>Practically no limits</td>
<td>Nickel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELBRODUR® H</td>
<td>- Casting surfaces with special contours for casting thin slabs</td>
<td></td>
<td>Nickel alloy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELBRODUR® G/GP/NS</td>
<td>- Straight or machined in accordance with casting radius</td>
<td></td>
<td>Metal-Ceramic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELBRODUR® NIB</td>
<td></td>
<td></td>
<td>Cobalt alloy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- With cooling slots or drilled cooling channels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Casting surfaces with special contours for casting thin slabs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Straight or machined in accordance with casting radius</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Cooling system in the shape of slots or drilled channels,</td>
<td>Practically no limits</td>
<td>Nickel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>depending on overall design</td>
<td></td>
<td>Nickel alloy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Metal-Ceramic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cobalt alloy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam-blank</td>
<td>Tubes</td>
<td>CuAg-NS</td>
<td></td>
<td>Up to 450 mm square; Larger sizes upon request</td>
<td>Chrome TOPOCRON®</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELBRODUR® G</td>
<td>- External contour parallel</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Internal geometries: parallel, part-tapered, multi-tapered, or</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>parabolic, and with special internal contours for casting beam-blanks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>with additional cooling channels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plates</td>
<td>CuAg-NS/NS</td>
<td></td>
<td>Practically no limits</td>
<td>Nickel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELBRODUR® G/GP/NS</td>
<td></td>
<td></td>
<td>Nickel alloy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELBRODUR® NIB</td>
<td></td>
<td></td>
<td>Metal-Ceramic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELBRODUR® B 95/B 95S</td>
<td></td>
<td></td>
<td>Cobalt alloy</td>
</tr>
<tr>
<td>Thin strip</td>
<td>Casting rolls</td>
<td>ELBRODUR® G/GP</td>
<td></td>
<td>Practically no limits</td>
<td>Nickel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELBRODUR® NIB</td>
<td></td>
<td></td>
<td>Nickel alloy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELBRODUR® B 95/B 95S</td>
<td></td>
<td></td>
<td>Metal-Ceramic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cobalt alloy</td>
</tr>
<tr>
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</tr>
</tbody>
</table>
Moulds for thin strip casting
As early as 1891, Sir Henry Bessemer drafted the principle of a casting machine in which the molten steel was supposed to solidify directly into steel strips between two casting rolls. Just over a hundred years later, his idea has become reality.

As a result of the unusually high surface/volume fractions that prevail in strip casting, great amounts of heat have to be conducted away by the casting rolls. KME can meet the extremely high demands on materials and the manufacturing precision required for all the various strip casting machines in use around the world. Customer-specific adaptations of the material characteristics to the cooling conditions and to the load situation are an important key to the successful development of the technology.

Since KME controls all stages along the entire process chain, it is possible for us to deliver specific engineered solutions for each individual customer and hence support start-up and production process.

KME manufactures according to OEM drawing and specification, including steel shafts, if requested for “ready to use” state.

Copper sleeves for thin strip casting
Material sciences and the development of copper alloy systems have for many years represented an important area for KME as the leading manufacturer of copper products. A major part of KME’s efforts in these fields is dedicated to the development of copper alloy systems for continuous casting moulds. Therefore, depending on the application and the range of properties required, the mould material can be adjusted using specially tailored alloys.

**Cu-GS**
DHP copper was developed as a standard material for mould tubes under normal service conditions at temperatures in the meniscus area of up to about 300 °C. The material displays excellent heat and creep resistance at high temperatures and its workability is good.

**CuAg-GS/NS**
Copper-silver alloys (CuAg) are used in applications in which higher thermal stresses and wall temperatures occur. CuAg alloys have a higher thermal conductivity, which means that the temperatures in the mould can be kept on lower levels. In addition, they have higher temperature resistance to softening than DHP-Cu.

**ELBRODUR® H**
ELBRODUR® H is a newly developed advanced material based on approved ELBRODUR® G alloy. This material is designed to bridge the gap between the highly conductive copper silver alloys and the creep resisting, precipitation hardened alloys like ELBRODUR® G. The material was developed for the application with net-shape-casting operations.

**ELBRODUR® G**
ELBRODUR® G is an age hardenable CuCrZr alloy which has excellent mechanical properties, both at room and higher temperatures. High heat conductivity, a very high softening temperature, high creep resistance and high resistance to alternating thermal stresses are exceptional properties that set this alloy apart from the copper alloys previously presented. The good combination of properties achieved in this material is made possible by the use of alloying elements and a special thermo-mechanical treatment (see Fig. 4).

**ELBRODUR® GP**
ELBRODUR® GP is an advanced material developed on the basis of the approved ELBRODUR® G. It has been possible to further improve this material’s properties through careful tuning of the chemistry and process control during manufacture.

**ELBRODUR® GP-NS**
ELBRODUR® GP-NS is an advanced material developed on the basis of the approved ELBRODUR® GP, but with a higher strength level. It was developed for near-net-shape-casting applications, such as beam-blank and thin slab moulds.

**ELBRODUR® GR**
The ELBRODUR® GR alloy is based on the material ELBRODUR® G and has been specially developed for moulds that work with electromagnetic stirring coils. The precisely controlled reduction of the electrical conductivity of this alloy, while maintaining the mechanical properties, ensures that the electromagnetic losses in the mould wall are kept to a minimum and no additional output is required from the coils. As a result of these special properties, there is no need to reduce the mould wall thickness. At the same time, sufficient strength of the mould is achieved.
ELBRODUR® B 95
This is a high-alloyed age hardenable CuCoBe based material which has medium conductivity, along with very good elevated temperature strength. This material is suitable for very special applications requiring reduced cooling, such as casting rolls.

ELBRODUR® NIB
This is a material based on CuNiBe. It has been developed specifically for use in moulds for near-net-shape-casting and other moulds that need to withstand particularly high stresses.

Its outstanding characteristics are high strength along with medium conductivity. Importantly, it has a special resistance to cracking when exposed to thermal stresses caused by large temperature fluctuations in the mould wall.
PERFORMANCE REQUIREMENTS FOR COPPER MATERIALS

<table>
<thead>
<tr>
<th>MOULD FUNCTION, TYPE OF EXPOSURE</th>
<th>PROPERTIES REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handling; assembly/disassembly</td>
<td>High basic hardness and strength</td>
</tr>
<tr>
<td>Transfer of superheat and heat loss of solidification</td>
<td>High thermal conductivity</td>
</tr>
<tr>
<td>High wall temperatures</td>
<td>Retention of high strength at the relevant operating temperatures</td>
</tr>
<tr>
<td>Mechanical stresses at high temperatures</td>
<td>High resistance to creep</td>
</tr>
<tr>
<td>Heavily fluctuating thermal stresses</td>
<td>High resistance to fatigue and cracking</td>
</tr>
<tr>
<td>(fluctuating meniscus level)</td>
<td>High hardness and resistance to wear</td>
</tr>
<tr>
<td>Strand/mould friction</td>
<td>Reduced electrical conductivity</td>
</tr>
<tr>
<td>Screening in electromagnetic stirring systems</td>
<td></td>
</tr>
</tbody>
</table>
**Fig. 1**
Recrystallisation/softening behaviour of KME mould materials versus standard copper (ETP Cu)

- E-Cu [ETP Cu]
- Cu-GS
- CuAg-GS/NS
- ELBRODUR® H
- ELBRODUR® G/GP/GP-NS
- ELBRODUR® B 95/NIB

**Fig. 2**
Creep characteristics of mould materials (temperature 200 °C/392 °F, stress 150 MPa)

- CuAg-GS/NS
- ELBRODUR® G/GP/GP-NS
- Cu-GS

**Fig. 3**
Hardness and electrical conductivity of KME mould materials

- Brinell hardness
- Electrical conductivity % IACS

**Fig. 4**
Effect of temperature on thermal conductivity of KME mould materials

- CuAg-GS/NS
- ELBRODUR® H
- ELBRODUR® G/GP/GP-NS
- Cu-GS
**WAVE® mould tube with flat top design**

**AMM® – ADVANCED MOULD MATERIALS**

### Table 1: KME materials for mould tubes

<table>
<thead>
<tr>
<th>Material Properties</th>
<th>Temperature</th>
<th>Units</th>
<th>Cu-GS</th>
<th>CuAg-GS</th>
<th>ELBRODUR® G</th>
<th>ELBRODUR® GR 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition (without copper)</td>
<td>%</td>
<td>0.03 P</td>
<td>0.09 Ag</td>
<td>0.65 Cr</td>
<td>0.65 Cr</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.006 P</td>
<td>0.1 Zr</td>
<td>0.1 Zr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5 others</td>
</tr>
<tr>
<td>Physical Properties</td>
<td>°C</td>
<td>°F</td>
<td>S·m/mm²</td>
<td>% IACS</td>
<td>W/(m·K)</td>
<td>10⁻³/K</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>20</td>
<td>68</td>
<td>48</td>
<td>83</td>
<td>50</td>
<td>29</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>20</td>
<td>68</td>
<td>340</td>
<td>377</td>
<td>355</td>
<td>50</td>
</tr>
<tr>
<td>Coefficient of thermal expansion</td>
<td>20–300</td>
<td>68–572</td>
<td>17.7</td>
<td>17.7</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Recrystallisation temperature</td>
<td>-</td>
<td>-</td>
<td>350</td>
<td>370</td>
<td>(800)</td>
<td>(800)</td>
</tr>
<tr>
<td>Softening temperature</td>
<td>-</td>
<td>-</td>
<td>580</td>
<td>580</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>20</td>
<td>68</td>
<td>120</td>
<td>125</td>
<td>128</td>
<td>128</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical Properties</th>
<th>°C</th>
<th>°F</th>
<th>MPa</th>
<th>MPa</th>
<th>MPa</th>
<th>MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 % Proof stress $R_{p0.2}$</td>
<td>20</td>
<td>68</td>
<td>290</td>
<td>290</td>
<td>360</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>392</td>
<td>260</td>
<td>260</td>
<td>335</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>662</td>
<td>(215)</td>
<td>(215)</td>
<td>295</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>932</td>
<td>(20)</td>
<td>(20)</td>
<td>(185)</td>
<td>(210)</td>
</tr>
<tr>
<td>Tensile strength $R_m$</td>
<td>20</td>
<td>68</td>
<td>310</td>
<td>310</td>
<td>430</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>392</td>
<td>265</td>
<td>265</td>
<td>400</td>
<td>390</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>662</td>
<td>(220)</td>
<td>(220)</td>
<td>340</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>932</td>
<td>(80)</td>
<td>(80)</td>
<td>(210)</td>
<td>(230)</td>
</tr>
<tr>
<td>Elongation $A_b$</td>
<td>20</td>
<td>68</td>
<td>16</td>
<td>16</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>392</td>
<td>14</td>
<td>14</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>662</td>
<td>(12)</td>
<td>(12)</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>932</td>
<td>(70)</td>
<td>(70)</td>
<td>(20)</td>
<td>(17)</td>
</tr>
<tr>
<td>Hardness HBW 2.5/62.5</td>
<td>20</td>
<td>68</td>
<td>95</td>
<td>95</td>
<td>130</td>
<td>130</td>
</tr>
</tbody>
</table>

Units: 1 MPa = 1 N/mm² = 0.102 kgf/mm² = 0.145 ksi; 1 W/(m·K) = 2.388 · 10⁵ cal/(cm·s·°C)

* Values may change with varying thermal and mechanical treatment due to geometry and manufacturing procedure
** Measurement according to DIN ISO 5182
( ) Values may change due to restricted reproducibility of measurement

22
### Table 2: KME materials for mould plates, block moulds and casting rolls

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Units</th>
<th>CuAg-GS</th>
<th>CuAg-NS</th>
<th>ELBRODUR® H</th>
<th>ELBRODUR® G/GP</th>
<th>ELBRODUR® GP-NS</th>
<th>ELBRODUR® B95</th>
<th>ELBRODUR® B95S</th>
<th>ELBRODUR® NIB</th>
<th>ELBRODUR® GR 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>20</td>
<td>68</td>
<td>0.09</td>
<td>0.1</td>
<td>0.1</td>
<td>0.65</td>
<td>0.65</td>
<td>1.0</td>
<td>1.4</td>
<td>1.5</td>
<td>0.65</td>
</tr>
<tr>
<td>20</td>
<td>68</td>
<td>0.006</td>
<td>0.004</td>
<td>Ag</td>
<td>0.1 Zr</td>
<td>0.1 Zr</td>
<td>0.1 Be</td>
<td>0.3 Be</td>
<td>0.2 Be</td>
<td>0.1 Zr</td>
</tr>
</tbody>
</table>

Units: 1 MPa = 1 N/mm² = 0.102 kgf/mm² = 0.145 ksi; 1 W/(m·K) = 2.388 · 10³ cal/(cm·s·°C)

* Values may change with varying thermal and mechanical treatment due to geometry and manufacturing procedure
** Measurement according to DIN ISO 5182
1) Values may change due to restricted reproducibility of measurement
2) Hardness HBW: 2.5 / 187.5 for ELBRODUR® B 95 and ELBRODUR® NIB
Nowadays the majority of all copper moulds around the world are hot-face coated – to either protect the copper against abrasive wear or diffusion of harmful elements or – to protect the surface quality of the cast product against copper pick-up (star cracks). KME has developed different advanced mould coatings to serve these special needs.
Copper materials have a relatively low hardness and thus low resistance to abrasive wear. For this reason, a high degree of wear can occur, mainly in the lower part of the mould. The main object of coating mould tubes and plates is to increase the service life of the mould, as well as an improvement in the product quality. KME has come up with future-oriented solutions by further developing and by using new coatings and coating-systems. New wear-protection layers and coating techniques are also being investigated in our laboratories.

**Coating of mould tubes**
The small size billet moulds, are particularly susceptible to wear. The hard chrome coating AMC®-HC 90 on the inside mould surfaces provides effective anti-wear protection which results in a substantial gain in mould lifetime.

**AMC®-ML**
In casting operations, mould tubes are exposed to an extreme variety of operational loads. In addition to a high thermal and high abrasive load, the steel melt often also introduces tramp elements into the process which cause a chemically induced damage. Such tramp elements like zinc or sulphur often originate from the steel scrap.

The formation of cracks and as a result a spalling of the coating in the meniscus level are typical damage patterns which necessitates a replacement of the mould tube.

As a countermeasure KME has developed the multi layer AMC®-ML coating to provide effective protection of the mould tube against the combined chemical, thermal and mechanical loads.

**TOPOCROM® coatings**
In addition to the well proven AMC®-HC 90 chrome coating, KME can also furnish mould tubes with TOPOCROM® coatings. The textured surface of this type of coating makes it possible for the frictional forces between the strand shell and mould wall to be reduced. TOPOCROM® coatings have shown less wear under abrasive test loads. This effect can be used to further improve the lifetime of mould tubes.

**Coating damage from zinc**
Zinc from the steel melt can initiate a specific failure mechanism in connection with chrome coatings. Vaporising zinc mainly from scrap makes its way to the copper surface by diffusing into the micro cracks which are always present in hard chrome. High mould temperatures encourage the diffusion, so that the problem mainly occurs in the mould meniscus area, especially if cooling conditions are unfavourable.

The copper reacts with the zinc forming brittle, and “bulky”, intermetallic phases of brass which result in premature chrome chipping.
Coating of mould plates
When it comes to coatings for mould plates, a distinction has to be drawn between
- coatings for metallurgical protection to improve the surface quality of the cast strand (e.g. prevention of star cracks), and
- anti-wear coatings to improve resistance to abrasion.

Depending on the distinction and the overall conditions at the plant the casting surfaces of the mould plates are either full-face coated or only partially with nickel, nickel alloys or special ceramic coatings. Also multi-layer coatings are possible.

Coatings for slab protection
When casting certain steel grades the surface quality of the cast strand can become impaired by copper particles picked up from the mould wall (especially in the lower part of a mould) which can lead to the development of star cracks. To avoid this defect, the mould plates of slab casters used for the production of these sensitive steel grades are protected with a nickel or nickel-alloy coating.

Anti-wear coatings
Considering the lower thermal conductivity of coating materials a decision for the right coating geometry has to be made.

As a result of the associated reduction in mould heat transfer, and because of the resultant higher wall temperatures which affect nickel adherence to the copper, thick nickel coatings have a major impact on the operational handling and relevant casting parameters. This puts definite limits on the maximum allowable nickel thickness in the meniscus area.

The table shows the effect of nickel plating thickness on heat transfer and wall temperature. From the point of view of caster operation, a reduction of approx. 3.8% in heat transfer with 3 mm nickel on the copper is not significant, but the accompanying 45°C increase in wall temperature causes considerable stresses in the nickel due to the difference in coefficients of thermal expansion of the two metals.

Due to that hairline cracks may develop in the nickel at the mould meniscus and can propagate into the copper. For this reason undue coating thickness should be avoided, especially in the meniscus area.

Nickel alloys, like KME's AMC®-HN 40 or AMC®-HWR are an interesting alternative to pure nickel layers. As a result of their greater hardness, they have good anti-wear properties with slightly lower thermal conductivity.

For the reasons outlined above, tapered nickel (alloy) coatings that are approx. 1.0 mm thick at the top and approximately 3.0 mm thick at the bottom end, or 2 – 6 mm thick partial coatings on the lower half of mould plates, represent optimal solutions with respect to both metallurgical and cost requirements.

The following table shows the effect of nickel plating thickness on heat transfer and wall temperature.

<table>
<thead>
<tr>
<th>Material: CuAg (DPS-Cu)</th>
<th>Ni coating thickness (mm)</th>
<th>Δ T wall (°C)</th>
<th>Δ heat transfer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall thickness: 35 mm</td>
<td>0.7</td>
<td>+ 11</td>
<td>- 0.9</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>+ 15</td>
<td>- 1.3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>+ 30</td>
<td>- 2.6</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>+ 45</td>
<td>- 3.8</td>
</tr>
</tbody>
</table>

Effect of nickel thickness on heat transfer and wall temperature
Calculation based on constant coefficients of heat transfer; heat flux approx. 1.8 MW/m².
For adjustable slab and bloom moulds, friction between the surfaces of the wide-face coppers and the edges of the narrow-face coppers leads to wear and the localised development of deep scores and scratches.

Here, the rate of wear can be reduced considerably by coating the edges of the adjustable narrow-face plates, which slide on the inside (hot-face) of the wide-face coppers, with a material that has greater hardness.

Beside the nickel and nickel-alloy coatings, KME can also supply metal-ceramic coatings (AMC®-HF). The high hardness of such coatings makes it possible to achieve considerable improvements in the lifetime, especially of narrow-face plates.

It can be seen that very complex interrelationships have to be taken into account when selecting a suitable coating and layer thickness. Recommendations can therefore only ever be made in relation to specific system and casting parameters. Close consultation between the system operator and the mould supplier is necessary to ensure that the appropriate coating systems are selected.

The selection of coating may furthermore depend on what possibilities exist in terms of mould maintenance and available re-coating services.
AMC® – Advanced Mould Coatings – hardness, thermal conductivity and thickness range

<table>
<thead>
<tr>
<th>Material</th>
<th>Hardness HV</th>
<th>Thermal conductivity W/(m·K)</th>
<th>Thickness range mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMC®-HN 20</td>
<td>220</td>
<td>90</td>
<td>2–6</td>
</tr>
<tr>
<td>AMC®-HWR</td>
<td>240</td>
<td>80</td>
<td>2–3</td>
</tr>
<tr>
<td>AMC®-HN 40</td>
<td>400</td>
<td>80</td>
<td>2–3</td>
</tr>
<tr>
<td>AMC®-HN 50</td>
<td>500</td>
<td>80</td>
<td>2–3</td>
</tr>
<tr>
<td>AMC®-HF 120</td>
<td>1200</td>
<td>30</td>
<td>0.1–0.6</td>
</tr>
<tr>
<td>AMC®-TOPOCR®M®</td>
<td>900</td>
<td>70</td>
<td>0.08–0.12</td>
</tr>
<tr>
<td>AMC®-HC 90</td>
<td>900</td>
<td>70</td>
<td>0.05–0.12</td>
</tr>
<tr>
<td>AMC®-ML Multi Layer</td>
<td>220/900</td>
<td>90/70</td>
<td>&gt;0.5</td>
</tr>
</tbody>
</table>

COATINGS FOR PLATES

2.0–6.0 mm HN 20 or 2.0–3.0 mm HN 40 / HWR
1.0–3.0 mm HN 20 or 1.0–2.0 mm HN 40 / HWR
0.3 mm + 3 mm HN 20 / HN 40 / HWR
1.0–3.0 mm HN 50

1.0–3.0 mm HN 20 / HN 40 / HWR + 0.025–0.05 mm HC 90
2.0–6.0 mm HN 20 + 0.025–0.05 mm HC 90
0.1–0.6 mm HF 120
AFM® – Advanced Funnel Mould: thin-walled copper plate + adapter plate

COATINGS FOR TUBES

0.08 mm–0.12 mm HC 90

0.1 mm ML

AMC®-TOPOCROM®
Material analysis in the central lab

Investigation of additive manufacturing technologies

Casting trial in the lab foundry

**RESEARCH AND DEVELOPMENT**

The aim of our work is to constantly improve our products for the benefit of our customers. To this end, KME continuously works on new materials and material processing techniques. For the development of moulds, we can draw on the core competence and knowledge of the entire Group. The R & D departments of the Group are positioned to cover the entire spectrum of tasks from the development of new mould materials to the support of the application of the new products.

In the development of new materials, new compositions are tested and familiar ones further developed. The R & D department for materials development solves both tasks. Here, mould materials used throughout the world today were developed at the beginning of the 1960s – such as ELBRODUR® G (CuCrZr) and others.

KME’s laboratory’s melting and casting facilities are capable of casting blocks weighing 3,500 kg which can be further processed at the production facilities. This means that new materials can be tested on industrial scale in short time and optimal production parameters can be determined in advance. A rolling mill and a press, together with annealing and salt-bath furnaces, are used for thermo-mechanical treatments within the department.
The development of materials is supported by the full range of chemical analysis (S-OES, XRF, ICP, F-AAS, etc.), including metallography, and by SEM electron microscopes, including EDX analysis systems. In the area of coatings, a galvanic laboratory was set up to facilitate their development. The technological laboratories for physics and mechanics are equipped with all of the necessary devices for testing and determination of material properties. This includes tests on creep, relaxation, softening, fatigue resistance, etc.

Destructive tests provide additional data, making it possible to investigate customer-specific conditions on particular stresses such as thermal/chemical problems in the meniscus area with softening and high temperature corrosion, deformation due to insufficient cooling or wear in the bottom/edge area.

R&D is also concerned with assessment of relevant new manufacturing technologies such as additive manufacturing, joining technologies and coating processes. In many cases, these processes can be investigated directly on-site at the Technology Centre and tested for applicability in the manufacture of moulds.

Today, basic laboratory research is supplemented by development work for the customer, focusing on improved productivity together with high reliability and service life in specific industrial applications. Thus, the primary aim of all development activities carried out by KME is to provide technical support to customers on how to optimise their facilities, processes and products.
Melting and casting
KME’s copper and copper alloys are produced on state-of-the-art melting and casting facilities. High purity cathodic copper is mainly used for producing the mould materials and the composition of the melt is monitored by appropriate analysis systems. Billets and slabs can be cast on different casting machines in different geometries to ensure that the dimensions of the starting size offers favourable conditions for the downstream production.

Forming
KME has access to both hot and cold rolling mills for forming the materials as well heavy-duty systems for extrusion, forging and ring rolling and heat treatment too. Special procedures and process sequences developed by KME ensure the manufacturing of complex geometries and dimensions, while maintaining the highest levels of quality.

Machining
Modern, precise CNC machine tools are available for machining of moulds. CAD/CAM-Systems for the design, manufacturing and quality control allow the manufacturing workpiece surfaces with extremely tight tolerances.

ADVANCED MOULD MANUFACTURING

Another major element of integrated mould technology is KME’s comprehensive production knowledge. Starting with material development, through the entire process chain from melting to casting and all the way to the final quality control, KME uses its vast experience to supply superior manufactured mould products.

Indication of trademarks named which are not in the ownership of KME:
- CSP® (SMS Group GmbH)
- ISP® (SMS Group GmbH)
- ESP® (Primetals Technologies Austria GmbH)
- Diamold® (Primetals Technologies Austria GmbH)
- fTSC® (Danieli & C. Officine Meccaniche S.p.A.)
- DUE® (Danieli & C. Officine Meccaniche S.p.A.)
- Topocrom® (Topocrom GmbH)
RESEARCH & DEVELOPMENT

ENGINEERING

MELTING

CASTING

Hot extrusion
  Drawing
  Cold forming
  Machining
  Plating
  Quality control

Hot rolling
  Cold rolling
  Cold forging

Hot forging
  Machining
  Plating
  Quality control

FINAL PRODUCT – TUBE

FINAL PRODUCT – PLATE
The use of high-quality products is absolutely imperative for the safe operation of continuous casting facilities. In order to ensure this, KME has all production and business processes certified to DIN ISO 9001.

This total in-house capability gives KME the start-to-finish control needed to pursue its business philosophy on all levels involved and through all stages of production.
Mould assemblies
From the smallest size billet mould to remotely adjustable slab moulds – KME builds and assembles all types of casting moulds complete with their complex drive and control systems.

Here, too, the uncompromising quality standards of KME are ensured through in-process quality control at all stages of a project, no matter whether it is a one-off job or the manufacture and assembly of a whole series of moulds. These services for maintenance and re-coating are for customer’s requirements on a worldwide basis.

Repair of mould tubes
As a matter of basic principle, mould tubes are designed as expendable items. Yet, in certain cases it may be economically worthwhile for a client to have his large-section mould tubes reworked.

Repair of mould plates
KME’s maintenance and repair services for mould plates include the proper remachining as well as repair of stud-welded moulds and possible re-coating of the copper, plus a complete overhaul of the entire mould assembly, if needed.

In the case of a complete mould overhaul, the mould will be dismantled and all its mechanical and supporting parts will be inspected and, if necessary, renewed. Like KME’s newly built moulds, the reassembled unit complete with the remachined copper – or with new copper, if necessary – will undergo a complete operational check.
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KME Germany GmbH & Co. KG — AMT® — Advanced Mould Technology
KME DEVELOPMENTS ON MOULD TUBES

1960
Manufacture of the first copper mould tubes for continuous casting of steel
Size range 80-120 mm

1963-1965
Development of a special manufacturing process to ensure a reproducible quality regarding
- high dimensional stability
- close tolerances
- Broadened size range
- All shapes

1965/66
Development and use of Cr-plated mould tubes

From 1980
Improvement of mould tube geometry to meet high-standard market requirements
- set up individual taper
- modification of corner radii
- modification of wall thicknesses
- closer tolerances

1982
Supply of first mould tubes with beam-blank moulds

1986/95
Supply of world’s largest mould tubes
Square
Round
Size
360 x 320 mm
ø 600 mm

1994/95
Supply of mould tubes with special geometries for high speed billet casting
- CCT®-Mould
- AMT®-Mould
- DIAMOLD®

Gun-drilled beam-blank moulds

2001
Development of improved chrome coating

2006
Development of homogenous cooling mould tubes

2008
Development of the AHE
Advanced High Efficiency Mould Tube

2009
Development of the ATM Advanced Tube Mould

2010
Development of the Textured Mould Tube

2012
WAVE®

2018
Round WAVE®
**KME DEVELOPMENTS ON MOULD PLATES**

- **1964**
  
  Start of manufacture and reconditioning of complete non-adjustable slab moulds
  
  Size 200 x 1700 mm

- **1966/70**
  
  Development and use of the special alloys of CuAg and ELBRODUR® G
  
  Extreme dimensional stability i.e. resistance to deformations through
  - high thermal conductivity
  - excellent high temperature strength
  - high creep resistance

- **1968**
  
  Supply of the first beam-blank moulds
  2-piece design
  
  Size 560 x 265/100 mm

- **1969/70**
  
  Supply of adjustable slab moulds

  Various sizes

- **1975**
  
  Continued development of electro-deposited nickel coatings + ceramic coatings

  Cr/Ni Ni Ni Ni+Cr HVOF

- **1986**
  
  Supply of the first beam-blank moulds
  4-piece design
  
  Size 685 x 225/50 mm

- **1988**
  
  Supply of the first thin slab moulds

  40 – 50 mm thickness
  x 900 – 1100 mm

- **1990**
  
  Supply of wide flange beam-blank moulds
  4-piece design
  
  Size 500 x 410/123 mm

- **1994**
  
  Supply of wide flange beam-blank moulds
  4-piece design
  
  Size 1120 x 500/130 mm

- **1998**
  
  Gun-drilled funnel mould with optimised cooling design by KME

- **2003**
  
  Development of the KME AFM® mould

- **2006**
  
  AFM® mould running in industrial-scale production

- **2007**
  
  Development of the KME ABBM beam-blank mould

- **2009**
  
  Development of the ASM® Advanced Slab Mould

- **2009**
  
  Development of the ESP®-Mould

- **2012/2013**
  
  Development and use of the special alloy ELBRODUR® GD-NS

  ELBRODUR® GP-NS
  - fatigue behavior
  - creep strength

- **2017**
  
  Development of the ATSM-Mould

- **2019**
  
  Supply of Mould with Fibre Optical Systems

  Size 500 x 410/123 mm
  40 – 50 mm thickness
  x 900 – 1100 mm

  Size 685 x 225/50 mm
  Size 560 x 265/100 mm
  Size 1120 x 500/130 mm